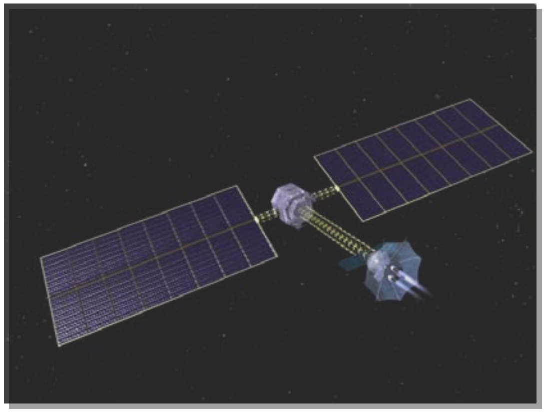
Fast Access Spacecraft Testbed (FAST)

Final Review

April 2006

Approved for Public Release – Distribution Unlimited

The Fast Access Spacecraft Testbed (FAST) Objectives



High power, high specific power

- High Power Payloads (comm, radar)
- LEO to GEO Orbit Transfer
- Rapid repositioning in GEO

Platform Focused Demonstration

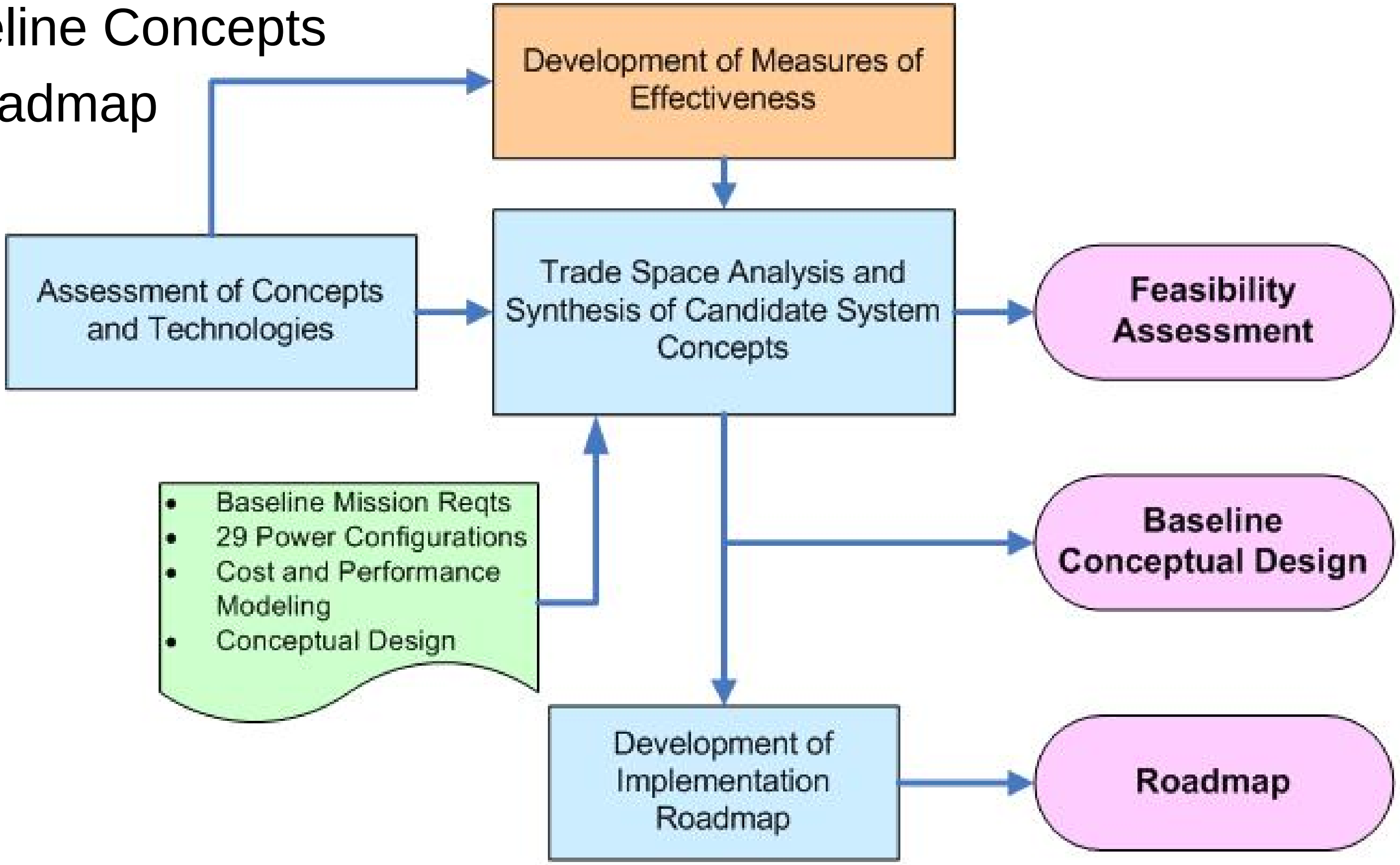
- *Demonstrate New Operational Capability*
- *Affordability for Multiple Use*
- *Multiple Payload Options on the Same Platform*

Predator as example: One platform, many options, many missions

Bringing the Benefits of Low Cost Mobile Platforms to Space

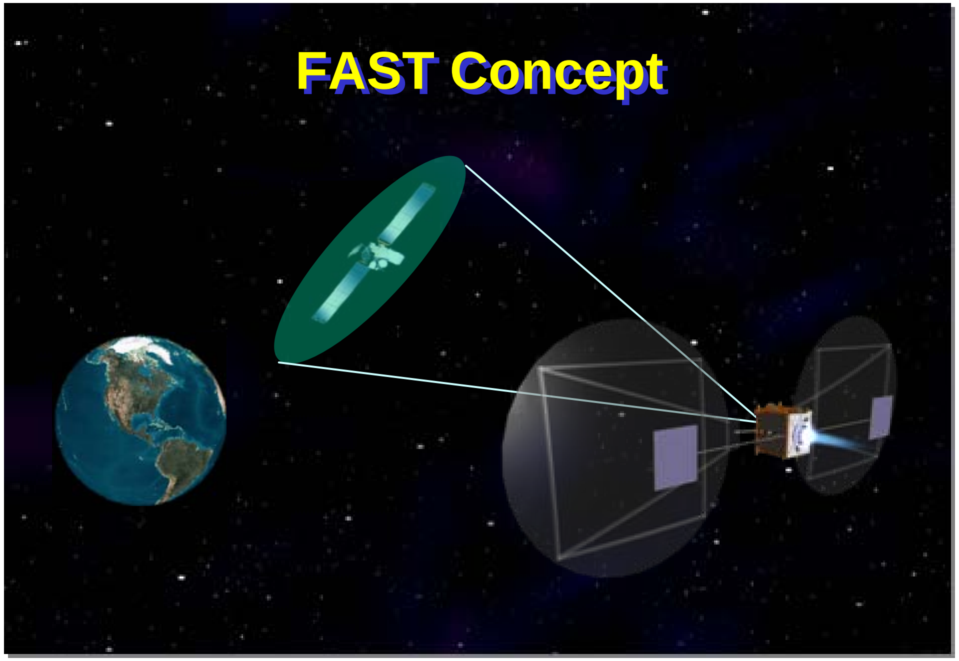
FAST Study Summary

- **Objectives**
  - Evaluate Feasibility
  - Derive Baseline Concepts
  - Define a Roadmap



Major Study Outputs

Comprehensive Review of Power Technologies Resulted in Several Feasible Candidates and a Roadmap



Mission Enabling

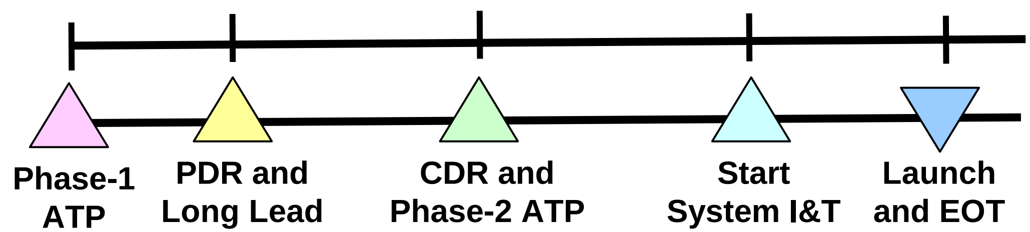
- **Very High Power (> 20 kW+) Enables agile high delta-V (> 6 km/sec)**
- **LEO to GEO transfer from lowest cost launch vehicles**
- **Anywhere within GEO belt in a week to allow one-on-many engagements.**

Technical Challenges

- **Platform Integration**
- **Factor of 5 Improvement in Power System**
- **Low Mass Deployables (< 1kg/m^2)**
- **Increase Factor of 2.5 in Heat Rejection Specific Power**
- **Dynamics and Control of Flexible Structures**

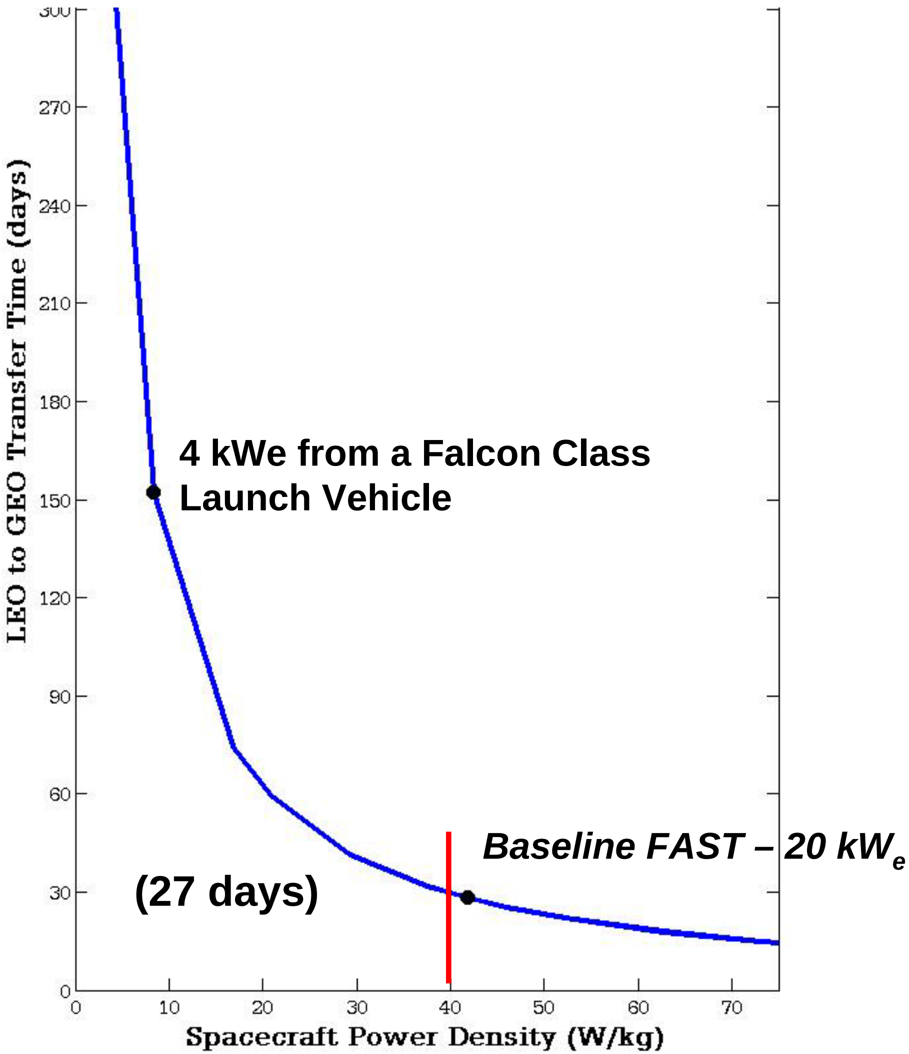
High Payoff Investments with Fall-Back Options

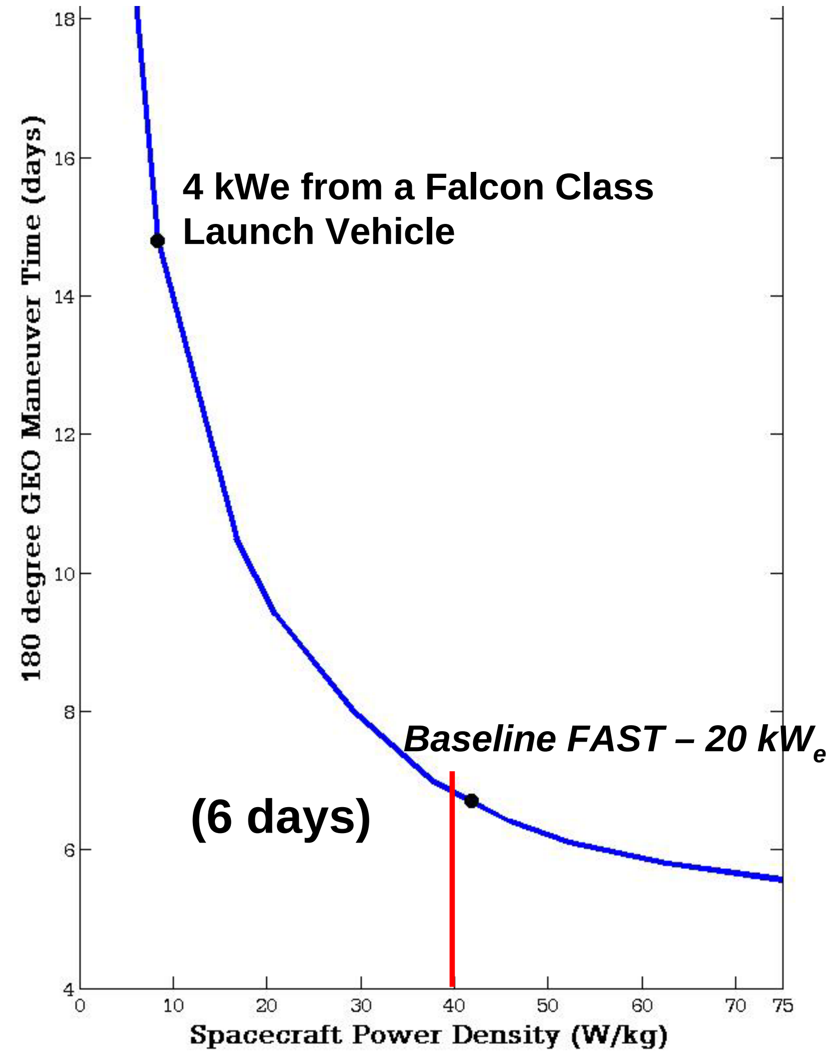
Programmatic Goals



Development & Ops Cost Goal TBD

High Power Density Enables Mobility





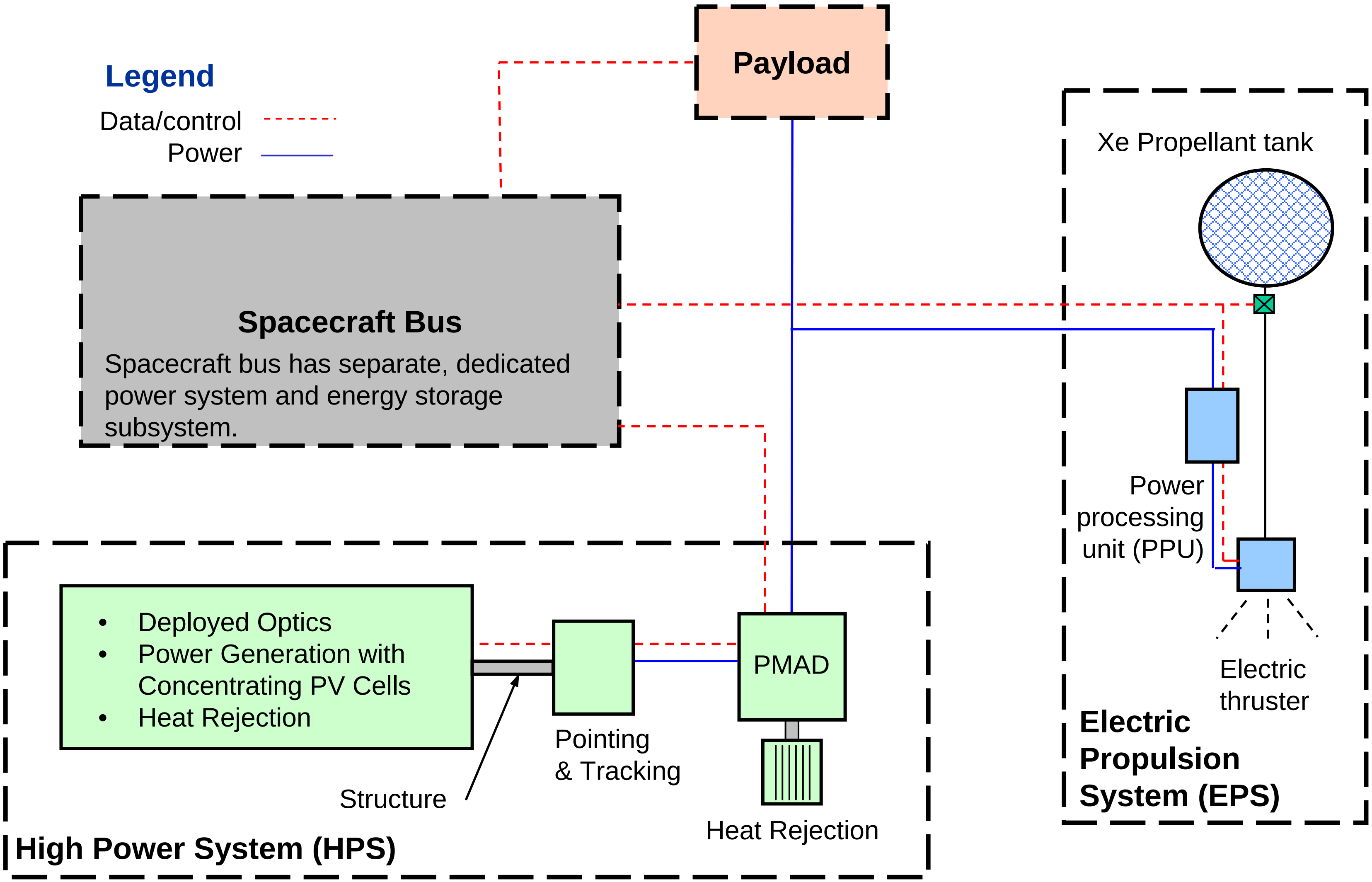
FAST Can Meet a Spacecraft Power Density Objective > 40 W/kg

Mission Enabling Features

- **Affordable**
  - Lowest Cost Launch; LEO – GEO Transfer
  - Enabled by Concentrating PV
  - Uses COTS Modular Bus Architecture
- **Responsive**
  - < 30 day LEO to GEO Transfer
  - Agile Maneuver; Traverse 180 degrees in GEO belt < 1 week
  - 10 Sorties
- **Capable**
  - Long standoff mission range for active sensing
  - More robust characterization at shorter ranges
- **Flexible**
  - High Mobility
  - Standard interfaces can host multiple payloads
  - Opportunity to demonstrate advanced technologies

Technology Pathfinder and Platform Demonstration for High Power Systems

Modular Spacecraft System Architecture



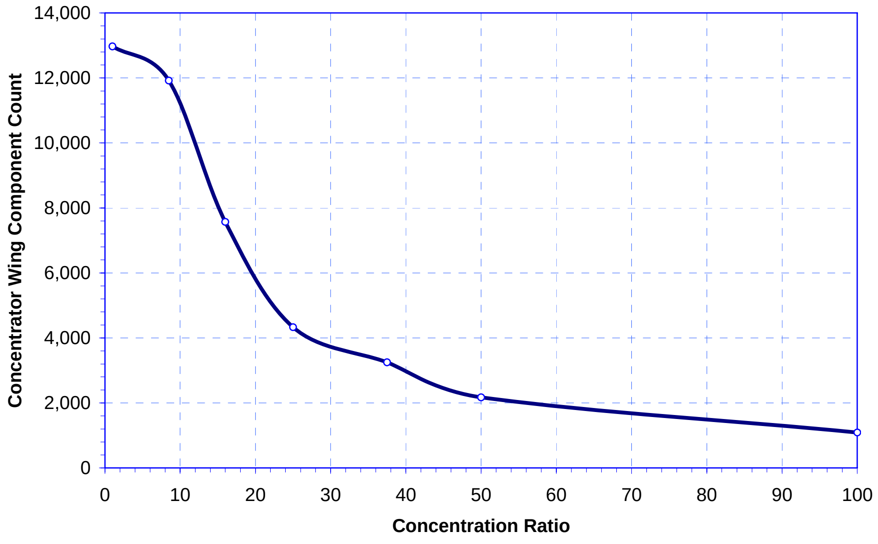
Architecture Key to Achieving Platform Objectives (mobility & payload flexibility)

Trade Studies Led to Concentrating Solar PV Approaches

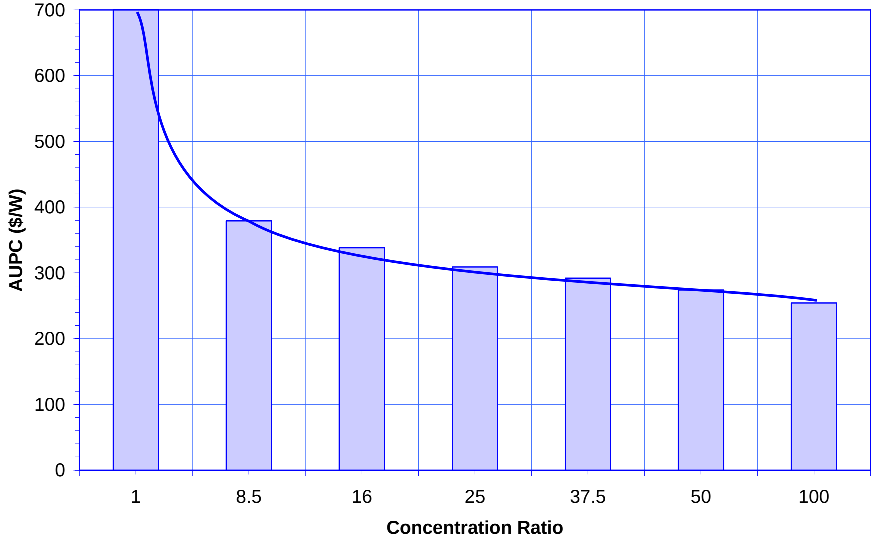
- **Lower recurring cost compared to traditional planar PV**
  - Highest W/kg
  - Highest kW/m^3

    Scalability to high power levels (50 kWe +)
  - Concentrating PV requires fewer parts to assemble, as compared to planar PV, and therefore has the potential to reduce the recurring cost (through mass and # of cells)
  - Radiation hardness
    - Orbit transfer through van Allen belts
    - Less shielding mass required for active cell area

Concentrator Wing Component Count (10 kW$_e$)



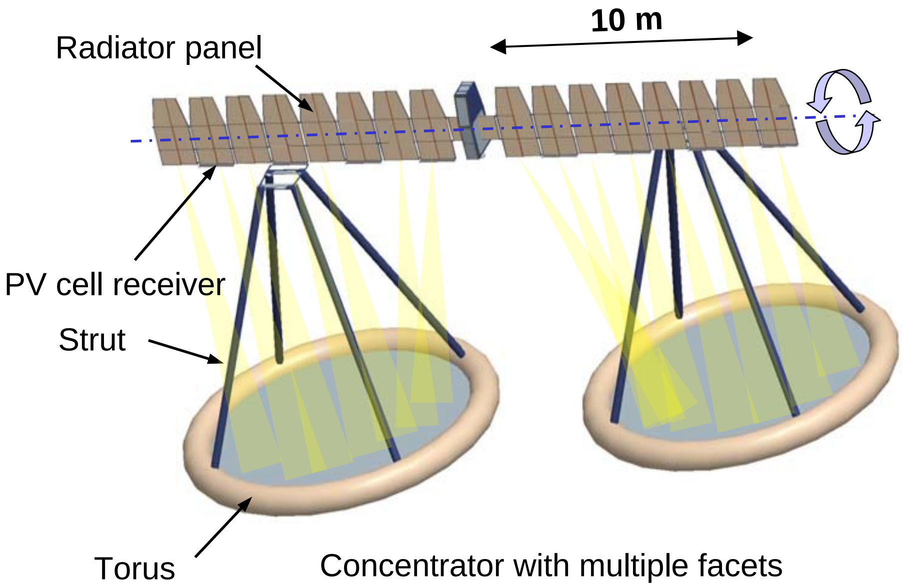
Power System Average Unit Production Cost (AUPC)



Several Options Exist for Meeting Platform Objectives

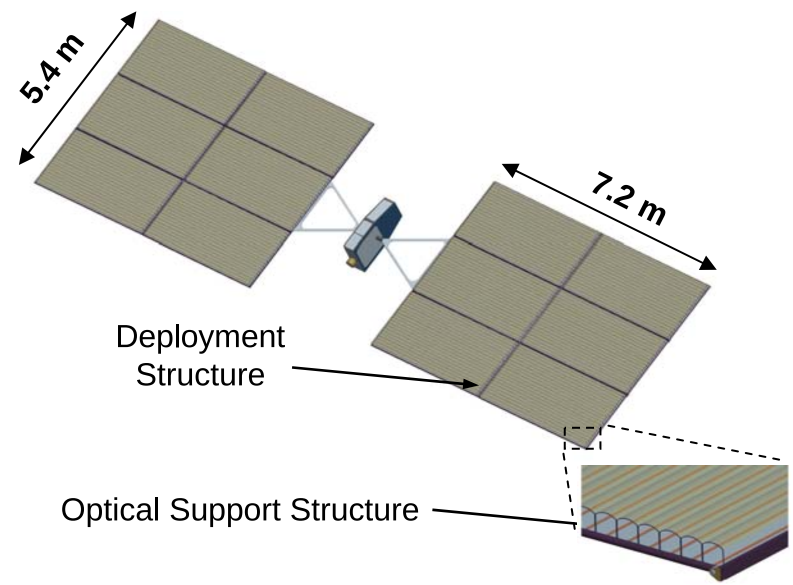
System Mass Allocations	Mass	Uncertainty	Margin/Growth	Margined Mass	
Payload Mass	45	10%	5	50	kg
Bus Mass	100	10%	10	110	kg
HPS	150	35%	53	203	kg
EPS	60	10%	6	66	kg
System Dry Mass	355	21%	73	428	kg
EPS Propellant	125	10%	13	138	kg
System Wet Mass	480	19%	90	570	kg

Candidate 1 – Point Focus with Inflated Optics



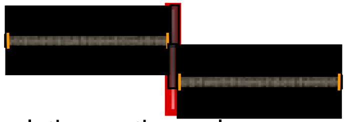
Pros: Inflatable Technologies, Low Part Count
Cons: Ground Testing Issues,

Candidate 2 – SLA with Square Rigger



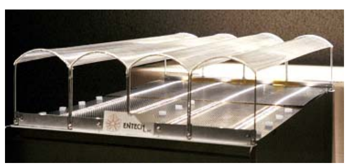
Pros: Shape Error Tolerance, Integral Radiator
Cons: Part Count, Large # of deployments

Enabling Power System Technologies



Revolutionary thermal management technology on backside of solar cells

Inflatable/rigidized struts & structure

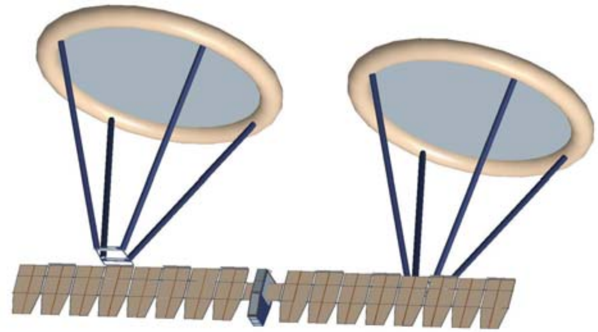


Thin-film Fresnel Lens

Thin-Film Facets

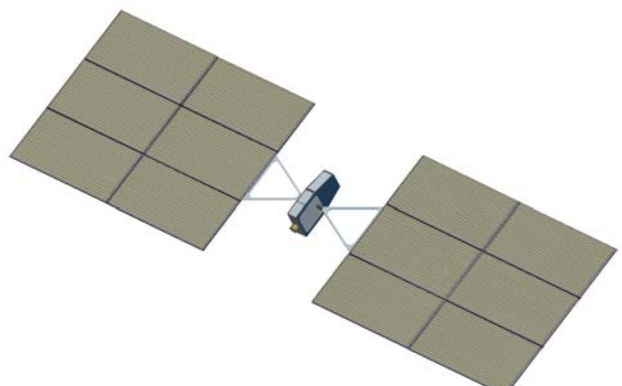
Composite Rigid Deployment

Point-Focus Concentrator PV Array



Deployed View

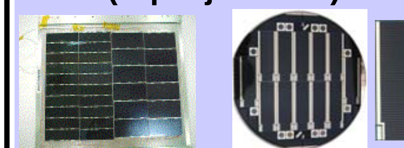
SLA Concentrator PV Array



Deployed View

Leverage Mature Technologies

Available PV cells (triple junction)



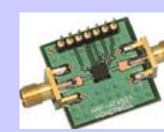
Available Electric Propulsion Technologies

Busek BHT-HD-8000

NEXT Ion Engine

Mature PMAD electronic component technologies

Silicon



Silicon on Insulator

High power density & innovative deployment approach enable efficient packaging for Falcon-class LV

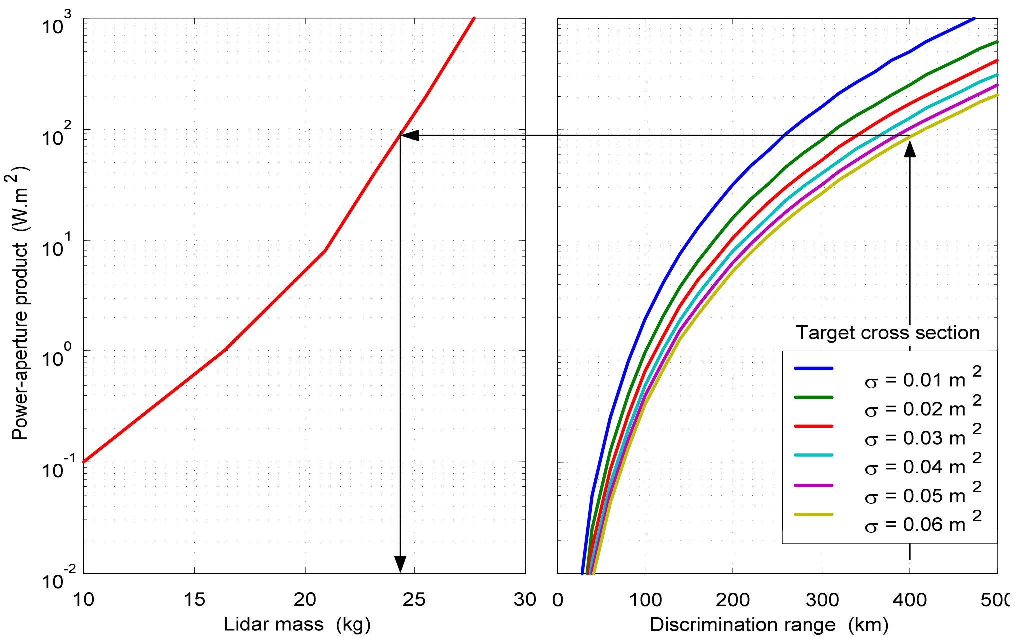
Notional Payload Options
Low Mass and Volume – Power is Unconstrained!

- **Imaging (Active and Passive)**
  - Active: Imaging LIDAR/LADAR, SAR, X-Ray Imager
- **Extremely High Bandwidth Communications**
  - Airborne 4x CDL at 274 Mbps x 4 = 1.1 Gbps (from GEO!)
  - Lasercom to achieve several Gbps
  - Ultra-high bandwidth data pipe to dedicated theaters, on demand
- **Long Range SSA (Hundreds or Thousands of Kilometers)**
  - Scanning radar with self cueing for track mode or imaging mode
  - “Mini” Pave Paws or Haystack in Space

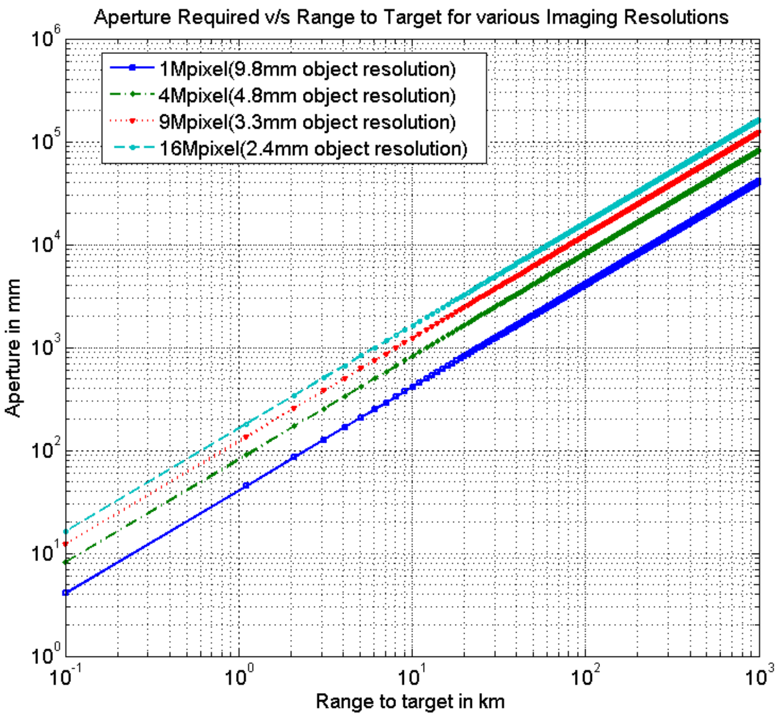
Payloads are now far less constrained by power limitations

Mobility and Power Enable New Payload Capabilities

Increased Power = Increased Capability (but mass also increases with power)



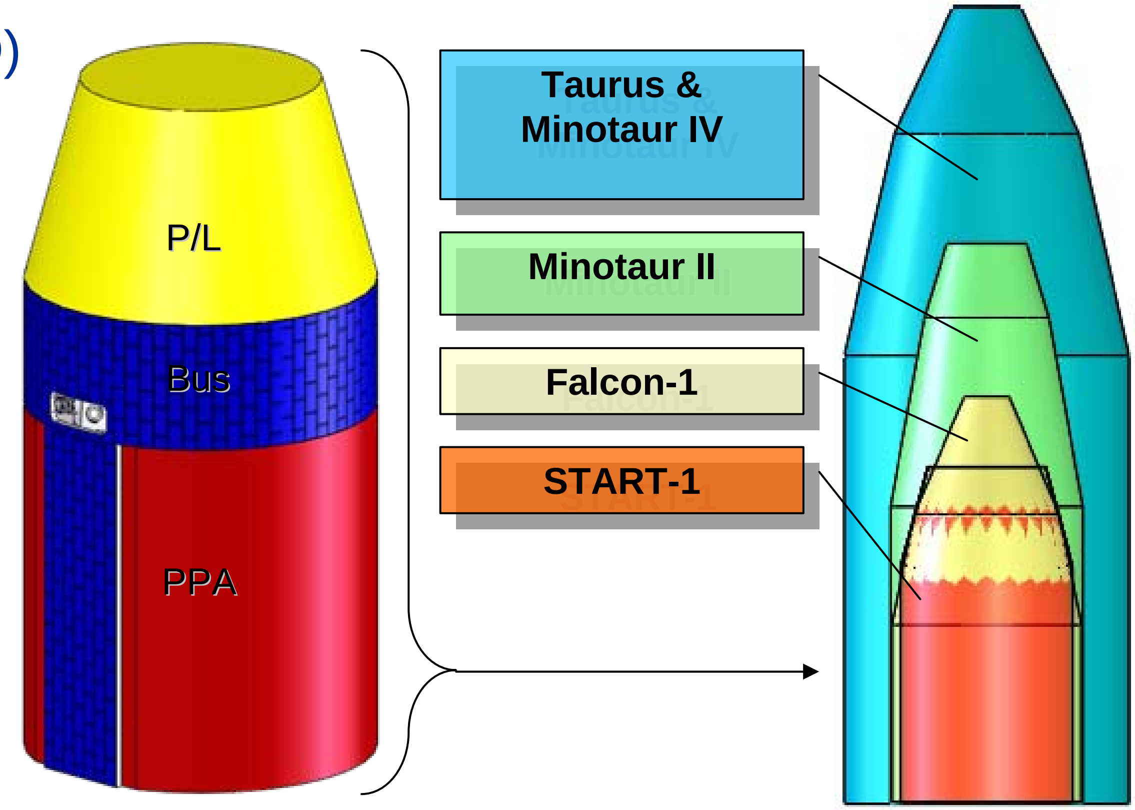
High Resolution Passive Imaging Enabled with Mobility



High Power with Constrained Mass Requires New Paradigm for Optimizing Platform Utility

Multiple Launch Vehicle Options

- **Possible Launch Vehicles**
  - Falcon 1 (570 kg to LEO)
  - START-1 (640 kg)
  - Minotaur II (530 kg)
  - Minotaur IV (1650 kg)
  - Taurus (1050 kg)
- **Volume Constraints Evaluated**



We Have Options but We Should Select a Size and Drive to the Optimum Configuration

Technical Challenges
High Payoff DARPA Hard

Challenges	FAST+ Needs	Technology/Development Needs	TRL	Fallback
Thermal Management System	- 52 kWt heat rejection for a 20 kWe power system - Operating temperature < max. solar cell operating temperature minus 20 ^oC	Carbon-Carbon Ti Solid State Heat Pipe - Performance testing for surface and axial heat flux capability - Space environment testing, including launch environment, micro-G & radiation	3	Water heat pipe radiator
Packaging & Deployment	Launch hardware envelope is defined by Falcon-class LV fairing and deployment on-orbit	Demonstrate packaging under launch loads and ground deployment testing in T/V tank after exposed launch environment	5	Larger fairing LV
Concentrator Optics	- Production lens with minimal optical inefficiency - Combined Sun-pointing error tolerance < 2 deg. Per axis	Optics accuracy demonstrated by ground demo testing for launch, vacuum, deployment, UV, AO, radiation environments and thermal cycles	5	Lower concentration ratio results in larger pointing error tolerance
Pointing & Control	Combined Sun-pointing error tolerance < 2 deg. per axis Torque Control Techniques	Sun-sensor and pointing control can achieve required accuracy; panel to panel alignment will require < 0.5 deg. /N, if N panels are designed	6	Lower concentration ratio results in larger pointing error tolerance
Thermal Cycles	~ 250 ^oC (ΔT) thermal shock for SA in and out of eclipse	Ground test demo for # of thermal cycles	5	Lower CTE mismatch with alternate materials